

Analysis of the Georges Bank and Gulf of Maine Cod Stocks

by

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Introduction

Currently, Atlantic cod (Gadus morhua) populations off the northeastern USA coast are managed as two distinct units: Georges Bank and southward (ICNAF Div. 5Z and Statistical Area 6), and the Gulf of Maine (ICNAF Div. 5Y) (New England Regional Fishery Management Council, April, 1977) (Figure 1). The following report presents an analysis of the status of these stocks and provides data on commercial and recreational catch statistics, research vessel survey abundance indices, fishing mortality estimates, and stock size estimates.

Catch Statistics

Tables 1 and 2 summarize the annual cod landings by the USA, Canada, and other countries during 1960-1976 from Georges Bank and the Gulf of Maine, respectively (see also Figures 3 and 4). Estimates of USA recreational catches from the combined stocks for 1960, 1965, 1970, and 1974 were derived from marine angler surveys (Clark 1962; Deuel and Clark 1968; Deuel 1973; Ridgely and Deuel unpublished MS). Allocation of the 1974 recreational catches to each of the stocks was accomplished by assigning all of the Maine and New Hampshire plus half of the Massachusetts sport cod catch to the Gulf of Maine while the remaining landings from Massachusetts, Rhode Island, New York and New Jersey were assigned to Georges Bank. Since catch data from the recreational surveys prior to 1974 were not listed by state, the ratio between the 1974 angler catches from each stock and the total recreational cod landed in 1974 (.187 for the Gulf of Maine; .813 for Georges Bank) was used to allocate the 1960, 1965, and 1970 total angling harvests between the two stocks. Catches in the intervening years between surveys were estimated by assuming that the ratio between the recreational and USA commercial landings

for each stock in each of the survey years was the same in the two years preceding and succeeding each survey year.

Estimated recreational catches from the Georges Bank area varied from about 8,100 tons (metric) to 16,100 tons during 1960-1976 and averaged 12,100 tons (for 1970-74, an interval in which two angler surveys were performed, the estimated recreational catch averaged 11,700 tons). During this same 17-year period, USA commercial catches ranged from 10,834 to 17,870 tons and averaged 14,150 tons annually. Canadian and total foreign catches rapidly increased from 1960 to 1966 and then subsequently declined to a low of 4,951 tons in 1976. In 1977, the Fishery Management Plan for Atlantic Groundfish (April 1977) authorized a harvest of 30,000 tons of cod (20,000 commercial, 10,000 recreational) from the Georges Bank stock for USA domestic interests and excluded any foreign fishing for these cod populations. The 1977 USA commercial quota was subsequently reduced to 16,650 tons when 3,350 tons of cod were allocated to Canada under terms of a USA/Canadian bilateral agreement.

In the Gulf of Maine, the recreational cod catch has remained fairly constant since 1960, fluctuating between 1,700 and 3,100 tons annually; the average for the period 1960-1976 was 2,600 tons. USA commercial landings during this period averaged 5,760 tons, although catches since 1968 have exceeded this value every year. For 1970-75, the domestic cod catch averaged 7,430 tons per year. Annual landings in recent years (since 1973) have increased by about 1,000 tons a year. Canadian and international catches of cod from the Gulf of Maine have been relatively insignificant; a combined

average of only 165 tons was taken annually from 1960-76. For 1977, an optimum yield of 7,300 tons (5,000 commercial, 2,300 recreational) of cod from the Gulf of Maine stock was established. As in the Georges Bank stock, the Groundfish FMP restricted harvests from the Gulf of Maine to USA fishermen alone.

Catch Composition

Table 3 contains estimates of the Georges Bank cod catch in numbers at age during 1960-76. The procedure used to derive these data was to (1) apply the length frequencies obtained from USA commercial samples to the commercial catches (USA and other countries) to deduce length frequencies, by year, of the total commercial catch, (2) apply age-length keys determined from spring and autumn USA bottom trawl surveys (1970-74) to the commercial length frequencies to obtain numbers at age. (The spring age-length key was applied to catches in the first two quarters of the year while the fall age-length key was applied to catches in the last half of the year), and (3) prorate upwards the numbers at age for the 1960-76 commercial catches to include the additional USA recreational catches.

Mean weights at age (Table 4) derived from a von Bertalanffy growth equation (Penttila and Gifford 1976) and the length-weight relationship, $\ln W_{(kg)} = 3.0521 \ln L_{(cm)} - 11.7231$, were applied to the numbers at age to obtain calculated catches (tons) for comparison with the observed catches (tons). Ratios between observed and calculated catches varied from 1.225 to 1.443 and averaged 1.355. These mean weights at age were applied to stock size numbers at age (Table 9) in all years to obtain annual stock biomass values at the beginning of each year.

Analysis of the catch composition in the Gulf of Maine area was not performed due to the paucity of commercial length frequency data.

Abundance Indices

USA research vessel bottom trawl survey catch-per-tow data (Table 5) indicate a stable level of abundance for the Georges Bank stock since 1963. The autumn catch-per-index (\log_e lbs) has varied between 1.10 (1968) and 1.80 (1973). Since 1973, the survey abundance index has increased annually; the 1976 index of 1.62 is the fifth highest value on record and is above the 1963-76 survey average of 1.43. Trends in the autumn linear catch-per-tow index have generally paralleled the \log_e catch pattern, although the former indices exhibit more between-year variability. The autumn survey indices of catch-per-tow in numbers (Table 6) from Subarea 5, Subdivision 5Ze, and Georges Bank depict a similar abundance trend to that of the survey biomass. Mean number per tow of both juvenile (<37 cm) and adult cod (\geq 37 cm) increased in Subdivision 5Ze and on Georges Bank from 1974-76. Prerecruit values (<37 cm) indicate that the 1971 and 1975 year-classes are the strongest in the Georges Bank population since 1966 (Table 6).

An index of cod in Southern New England and the Middle Atlantic area was derived only from spring bottom trawl surveys since few fish are taken in these southerly sectors during autumn. Both stratified mean catch-per-tow indices (pounds and numbers, Table 7) show essentially the same trend; abundance (\log_e values) was stable between 1968-72, increased markedly in 1973, and subsequently declined through 1976. In 1977, mean catch-per-tow showed an increase in these southerly areas.

Spring survey abundance indices from 1973 onward are not directly comparable to those in former years since the recent year surveys have been performed with a No. 41 Yankee trawl while previously a No. 36 Yankee trawl was used. Hence, the pronounced increase in abundance noted in 1973 may have reflected differences in sampling gear. The apparent increase, however, may also have been real since the autumn Georges Bank bottom trawl survey catch-per-tow indices (pounds) (Table 5) exhibited an increase in 1973 from 1972. The autumn surveys have always been conducted using a No. 36 Yankee trawl.

Differences in the survey abundance trends between the southern and northern components of the Georges Bank stock are difficult to interpret. The mobility of the New Jersey and Southern New England cod groups (Wise 1962) due to migration and hydrographic conditions makes these populations difficult to sample and assess with a standard survey design. Equally, the affinities of these groups to the more northerly populations still remains uncertain.

USA commercial catch-per-day indices for the Georges Bank area (Figure 5) showed the same abundance trends as the autumn bottom trawl surveys during 1963-67. Subsequently, however, the commercial landings-per-day-fished rose markedly while the survey catch-per-tow remained level. Because the reduced abundance of haddock affected the fishing patterns for cod after 1967, Brown and Heyerdahl (1972) suggested that the post-1967 commercial indices do not accurately estimate cod abundance. Accordingly, the commercial indices from 1967 onwards were adjusted with the survey indices to eliminate the bias introduced by the recent changes in fishing practices.

Standard days fished (Table 8), derived from the adjusted commercial indices, indicate that changes in catch from the Georges Bank area result primarily from changes in effort. Both total commercial landings and effort in this fishery decreased during 1974-76, with the 1976 values being the lowest in the past decade.

Abundance indices for the Gulf of Maine stock are limited to results of the autumn bottom trawl surveys (Tables 5 and 6). Mean catch-per-tow (numbers and pounds) was relatively stable from 1963-1967, increased in 1968, stabilized at a slightly lower level during 1969-71, and then decreased until 1974. Abundance increased in 1975 due to good recruitment but decreased markedly in 1976. Indices for 1976 were the lowest in the history of the trawl survey.

Georges Bank Stock

Virtual Population Analysis

Stock size estimates (numbers) derived from virtual population analysis (Table 9) of the Georges Bank cod catch in numbers at age indicate that population abundance substantially decreased from 1967 to 1974. Total stock size was reduced by 40% in this interval while spawning stock size (age 3 and older) decreased 28%. Since 1974, both total and spawning stock abundance have generally stabilized or increased slightly.

Georges Bank stock biomass trends (Table 9, Figure 6) are largely consistent with the fluctuations in population numbers. Spawning stock biomass increased from 1960 to 1965, but decreased by about 60% from 1965 to 1973. Since 1973, spawning biomass has been about 50,000 tons; a stock

level resembling that of 1960. The 1977 spawning stock biomass (about 60,000 tons) represents a 31% increase in size from 1976 and suggests that stock recovery is transpiring. The recent appearance of two strong year-classes in the Georges Bank fishery and the overall effort reduction since 1974 may have contributed much to this improvement.

The VPA stock estimates as presented here must be viewed in light of several procedural and data estimation factors. These include: (1) inclusion of recreational catches of uncertain accuracy into the VPA; (2) proration of the recreational landings on the basis of commercial length-frequency and survey age-length data; (3) use of age-length keys and length weight relationship based on 1970-74 data, to derive biomass from numbers and length data and (4) dependence of recent population size estimates on a terminal F value (0.55) derived solely through iterative procedures based on relative catch levels. While the relative inaccuracy, if any, of the stock size estimates due to the above factors cannot be presently evaluated, the VPA stock size trends do seem to reflect events in the recent Georges Bank fishery.

Fishing Mortality

Fishing mortality estimates (F) for Georges Bank cod, by size group, are listed in Table 10. Fishing mortality for ages 3 and older fluctuated only moderately during 1960-64 but increased during 1965-72 from 0.447 to 0.765. Since 1973, estimates of F have stabilized between 0.54 and 0.63. The increase in fishing mortalities during the late 1960's and early 1970's probably resulted from the expansion in fishing effort during 1965-1969 (Table 8), and the subsequent poor recruitment of the 1968-1970 year-classes (Table 9).

Cod are fully recruited to the Georges Bank fishery at age 3 and older based on the age-specific mortality rates (Table 11). Partial recruitment at ages 1 and 2 (the percentage of F at these ages compared with the weighted mean for ages 3 and older) varied from 0.5 to 5.8% and 32.7 to 129.4%, respectively (Table 11). The selection factor used for the 1975 year-class at age 1 in the VPA (0.15) resulted in an age-specific F of 0.08 and a year-class size of 4.8 million fish. This low year-class size compared to age 1 estimates for previous years and the 1976 juvenile cod survey catch-per-tow value implied that partial recruitment was greatly overestimated. Accordingly, the average age 1 stock size from 1968-71 (20 million fish) was used as a conservative estimate of 1976 age 1 stock size. Partial recruitment resulting from the F value required to generate this year-class size was 3.4%. Although this value is somewhat higher than previous partial recruitment values (Table 11), it appears representative with respect to the large recent-year catches taken from the two strong year classes (1971 and 1975) evident in the population between 1972 and 1976. An improved estimate will be available following the 1977 fishing season.

Yield Per Recruit

Maximum yield per recruit of Georges Bank cod occurs at an F -level of 0.3 (Brown and Heyerdahl 1972). The level of F for fully recruited age-groups prevailing since 1973 has been between 0.54 and 0.63 and has thus remained above the F_{\max} level.

Gulf of Maine Stock

Although a detailed assessment (virtual population analysis) cannot be performed for this stock; the annual increases in catch evident since 1974 (Table 2) and the concomitant decreases in bottom trawl survey abundance indices (Tables 5 and 6) suggest recent decreases in stock biomass. The trend (since 1974) of catches to exceed the estimated MSY level of 10,000 tons (New England Regional Fishery Management Council, April 1977) further implies recent increases in F . While the survey data indicate that some of the increased harvest may be due to the existence of one or two strong classes in the fishery since 1970, fishing mortality certainly remains in excess of F_{max} (0.30).

References

- Brown, B.E., and E. G. Heyerdahl. 1972. An assessment of the Georges Bank cod stock (Div. 5Z). Int. Comm. Northw. Atlant. Fish. Res. Doc. 72/117.. Ser. No. 2831 (mimeographed).
- Clark, J. R. 1962. The 1960 salt-water angling survey. U.S. Dept. Interior, Bur. Sport Fish and Wildl., Circ. 153: 36 p.
- Deuel, D. G. 1973. 1970 salt-water angling survey. NOAA, Nat. Mar. Fish. Serv., Current Fish. Stat. No. 6200: 54 p.
- _____, and J. R. Clark. 1968. The 1965 salt-water angling survey. U.S. Dept. Interior, Bur. Sport Fish. and Wildl., Resource Publ. 67: 51 p.
- Heyerdahl, E., and P. Wood. 1976. Data summaries prepared for Subarea 5 cod assessments. Int. Comm. Northw. Atlant. Fish., Working Paper 76/IV/70 (mimeographed).

- New England Regional Fishery Management Council. 1977 (April). Final Environmental Impact Statement for the Implementation of a Fishery Management Plan for Atlantic Groundfish. 195 p.
- Penttila, J. A., and V. M. Gifford. 1976. Growth and mortality rates for cod from the Georges Bank and Gulf of Maine areas. Int. Comm. Northw. Atlant. Fish., Res. Bull. 12: 29-36.
- Ridgely, J. E., and D. G. Deuel. Unpubl. MS. Participation in marine recreational fishing. Northeastern United States, 1973-74, Phase II.
- Wise, J. P. 1962. Cod groups in the New England areas. Fish. Bull. 63(1): 189-203.

Table 1. Cod landings (metric tons) from Georges Bank (ICNAF Div. 5Z) during 1960-1976.

Year	USA		Canada	Other countries	Total
	Commercial	Recreational			
1960	10,834 ³	11,395 ¹	19	-	22,248
1961	13,998	14,838	223	55	29,114
1962	15,232	16,146	2,404	5,455	39,237
1963	13,904	13,487	7,832	5,217	40,440
1964	12,325	11,955	7,108	5,732	37,120
1965	11,410	11,029 ¹	10,598	16,325	49,362
1966	11,794	11,440	15,601	25,468	64,303
1967	12,742	12,360	8,232	15,360	48,964
1968	14,967	13,620	9,127	18,663	56,377
1969	16,356	14,884	5,997	15,071	52,308
1970	14,535	13,246 ¹	2,583	8,091	38,455
1971	15,795	14,393	2,979	8,921	42,088
1972	13,140	11,957	2,545	8,945	36,587
1973	15,933	8,922	3,220	9,387	37,462
1974	17,870	10,055 ¹	1,374	7,448	36,747
1975	15,240	8,534	1,845	6,912	32,531
1976 ²	14,491 ³	8,115	2,304	2,647	27,557

¹From angler survey; remaining years estimated.

²Provisional.

³Includes 5NK landings.

Source: US commercial and foreign landings from ICNAF Statistical Bulletins 1960-1965; 1966-1975 data from ICNAF Summary Document 77/VI/8; 1976 data from ICNAF Working Paper 77/IV/1.

Table 2. Cod landings (metric tons) from the Gulf of Maine (ICNAF Division 5Y) during 1960-1976.

Year	USA		Canada	Other countries	Total
	Commercial	Recreational			
1960	3,448	2,621 ¹	129	-	6,198
1961	3,216	2,444	18	-	5,678
1962	2,989	2,272	83	-	5,344
1963	2,595	1,713	3	133	4,444
1964	3,226	2,129	25	-	5,380
1965	3,780	2,537 ¹	148	-	6,465
1966	4,008	2,645	384	-	7,037
1967	5,676	3,746	297	-	9,719
1968	6,360	2,417	61	-	8,838
1969	8,157	3,100	59	268	11,584
1970	7,812	3,046 ¹	26	423	11,307
1971	7,380	2,804	119	163	10,466
1972	6,776	2,575	53	88	9,492
1973	6,069	1,821	68	9	7,967
1974	7,639	2,313 ¹	120	5	10,077
1975	8,903	2,671	86	26	11,686
1976 ²	9,878	2,963	7	-	12,848

¹From angler survey; remaining years estimated.

²Provisional.

Source: US commercial and foreign landings from ICNAF Statistical Bulletins 1960-1965; 1966-1975 data from ICNAF Summary Document 77/VI/8; 1976 data from ICNAF Working Paper 77/IV/1.

Table 3 . Atlantic cod catch (commercial and recreational) (thousands of fish) from Georges Bank (ICNAF Div. 5Z+SA6) during 1960-1976.

Year-class	YEAR																
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
1949	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1950	5	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1951	19	12	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1952	33	32	8	11	-	-	-	-	-	-	-	-	-	-	-	-	-
1953	72	59	36	56	11	-	-	-	-	-	-	-	-	-	-	-	-
1954	292	103	72	127	52	20	-	-	-	-	-	-	-	-	-	-	-
1955	531	205	141	220	113	55	55	-	-	-	-	-	-	-	-	-	-
1956	1,653	457	448	303	214	109	236	6	-	-	-	-	-	-	-	-	-
1957	3,151	1,406	730	703	323	253	528	73	5	-	-	-	-	-	-	-	-
1958	3,702	4,916	2,503	1,006	764	371	873	138	76	15	-	-	-	-	-	-	-
1959	312	0,226	7,373	2,742	1,079	866	988	329	137	59	12	-	-	-	-	-	-
1960	-	549	6,560	5,063	2,450	1,135	1,316	422	244	105	39	4	-	-	-	-	-
1961	-	-	283	3,648	4,051	2,617	1,600	746	324	201	87	56	7	-	-	-	-
1962	-	-	-	78	2,703	5,781	2,486	1,156	735	267	138	124	40	11	-	-	-
1963	-	-	-	-	65	7,561	3,926	2,952	1,043	612	210	217	90	20	20	-	-
1964	-	-	-	-	-	454	4,811	7,117	3,180	817	542	354	170	50	56	5	-
1965	-	-	-	-	-	-	211	5,039	0,220	2,914	890	868	256	89	109	17	2
1966	-	-	-	-	-	-	-	242	10,500	8,931	3,031	1,168	606	124	162	55	19
1967	-	-	-	-	-	-	-	-	192	9,879	6,600	2,872	862	316	187	82	30
1968	-	-	-	-	-	-	-	-	-	68	2,765	4,524	2,380	450	355	150	96
1969	-	-	-	-	-	-	-	-	-	-	50	3,200	4,927	1,272	404	477	175
1970	-	-	-	-	-	-	-	-	-	-	-	84	3,089	4,714	1,564	786	578
1971	-	-	-	-	-	-	-	-	-	-	-	-	130	15,453	6,368	2,616	796
1972	-	-	-	-	-	-	-	-	-	-	-	-	-	1,084	7,620	4,600	1,614
1973	-	-	-	-	-	-	-	-	-	-	-	-	-	-	272	4,134	3,244
1974	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	222	4,234
1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	334
Total	9,770	16,127	10,165	14,037	11,825	19,230	17,030	18,990	24,656	23,860	13,364	13,471	13,357	23,599	17,197	13,224	11,122
Obs. wt. ¹	22,248	29,114	39,237	40,440	37,120	49,362	64,303	48,694	56,377	52,308	38,455	42,088	36,587	37,462	36,747	32,531	27,557
Calc. wt. ^{1,2}	15,691	21,011	28,322	30,724	28,164	35,825	52,482	38,136	41,220	38,394	27,990	31,433	26,946	25,956	26,400	24,125	20,267
Obs/calc.	1.418	1.386	1.305	1.316	1.318	1.378	1.225	1.277	1.368	1.362	1.374	1.339	1.358	1.443	1.388	1.348	1.360

¹Metric tons

²Using mean weights at age from Table 4.

Table 4. Mean weights at age (kg) for Atlantic cod.

Age	1	2	3	4	5	6	7	8	9	10	11
kg	.17	.62	1.41	2.51	3.88	5.45	7.15	8.93	10.75	12.55	14.31

Source: USA bottom trawl survey length-weight equation, $W_{(kg)} = e^{(-11.7231 + 3.0521 \log_e L_{(cm)})}$, and von Bertalanffy growth equation, $\ell_t = 148.1 (1 - e^{-.120(t + 0.616)})$, (Penttila and Gifford, 1976). Resultant age-weight equation is:
 $W_{t(kg)} = 34.16 (1 - e^{-1.20(t+0.616)})^{3.0521}$

Table 5. Stratified mean catch (pounds) per tow (linear and \log_e) of cod from USA autumn bottom trawl surveys, 1963-1976. See Figure 2 for location of sampling strata.

Year ¹	Georges Bank ²		Gulf of Maine ³	
	Total (linear)	Total (\log_e)	Total (linear)	Total (\log_e)
1963	24.2	1.75	24.4	1.35
1964	15.7	1.30	31.0	1.15
1965	15.9	1.35	16.3	1.20
1966	11.1	1.20	17.6	1.30
1967	18.4	1.75	12.5	1.35
1968	11.7	1.10	26.5	1.85
1969	10.9	1.30	20.9	1.45
1970	17.1	1.40	22.4	1.65
1971	13.4	1.25	22.5	1.25
1972	31.3	1.75	17.7	1.80
1973	42.0	1.80	11.9	1.35
1974	11.2	1.05	12.2	1.35
1975	19.1	1.35	11.7	1.40
1976	24.0	1.62	9.2	1.18

¹Values for 1963-1975 derived from Figure 15, ICNAF Working Paper 76/IV/70 (Heyerdahl and Wood, 1976).

²Strata 13-25.

³Strata 26-30, 36-40.

Table 6 . Stratified mean catch (number) per tow of cod from USA fall bottom trawl surveys, 1963-1976.
See Figure 2 for location of sampling strata.

Year	ICNAF Subarea 5 ¹			ICNAF Subdivision 52e ²			ICNAF Division 5Y ³			Georges Bank ⁴		Gulf of Maine ⁵	
	<37 cm	≥37 cm	Total	<37 cm	≥37 cm	Total	<37 cm	≥37 cm	Total	Total	Total	Total	Total
											(linear scale)	(log _e scale)	(linear scale)
1963	0.40	2.60	3.00	0.21	2.25	2.46	1.18	3.37	4.54	2.80	0.76	3.79	0.71
1964	0.10	1.86	1.96	0.15	1.50	1.65	0.13	2.13	2.26	1.80	0.58	2.57	0.53
1965	0.55	1.50	2.05	0.56	1.69	2.25	1.37	3.45	4.82	2.72	0.70	2.08	0.55
1966	0.70	1.54	2.24	1.16	1.50	2.66	0.47	3.20	3.67	3.09	0.74	2.43	0.61
1967	1.54	2.09	3.63	2.99	2.04	5.03	0.26	2.33	2.59	6.62	1.10	1.64	0.60
1968	0.06	2.09	2.15	0.10	1.65	1.75	0.07	4.32	4.39	2.12	0.56	2.80	0.84
1969	0.06	1.30	1.44	0.05	1.17	1.22	0.12	2.67	2.80	1.41	0.50	1.77	0.59
1970	0.75	2.07	2.82	0.49	2.32	2.81	2.11	2.87	4.92	3.25	0.77	3.14	0.69
1971	0.56	1.51	2.07	0.41	1.32	1.73	1.72	2.94	4.66	2.04	0.63	2.80	0.60
1972	3.72	2.70	6.50	3.92	3.45	7.37	6.60	3.44	10.04	8.39	1.05	5.96	0.86
1973	1.27	3.24	4.51	1.12	5.34	6.45	2.73	2.13	4.86	7.87	1.08	2.85	0.66
1974	0.69	1.56	2.25	0.40	1.51	1.91	1.86	2.75	4.62	2.24	0.53	2.77	0.65
1975	1.44	2.25	3.69	1.71	2.21	3.92	2.40	4.01	6.41	4.11	0.65	3.94	0.79
1976	1.20	2.31	3.51	2.30	3.57	5.87	0.25	1.90	2.15	6.68	0.92	1.38	0.51

Strata 9-30, 36-39
Strata 9, 10, 13, 16-25
Strata 26-28, 37-40

⁴Strata 13-25
⁵Strata 26-30, 36-40.

Table 7. Stratified mean catch (numbers and pounds) per tow (linear and \log_e) of cod from USA spring bottom trawl surveys taken in Southern New England and the Middle Atlantic areas (strata 1-2, 5-6, 9-10, 65, 69-70, 73-74), 1968-1977. See Figure 2 for location for sampling strata.

Year ¹	Mean number per tow (linear)	Mean number per tow (\log_e)	Mean weight (lbs) per tow (linear)	Mean weight (lbs) per tow (\log_e)
1968	1.14	.40	6.29	.89
1969	1.47	.40	8.73	.95
1970	.74	.29	7.35	.74
1971	.61	.30	6.10	.81
1972	.62	.22	5.80	.59
1973	2.58	.69	11.94	1.25
1974	.73	.34	6.78	.81
1975	.72	.31	7.47	.82
1976	.42	.18	4.79	.41
1977	.45	.33	4.69	1.27

¹1968-1972 spring survey catches were made with No. 36 trawl.
 1973-1977 spring survey catches were made with No. 41 trawl.
 No adjustment has been made in catches for the gear differences.

Table 8. Landings, USA catch per day (adjusted and unadjusted), and standard days fished (adjusted and unadjusted) for Georges Bank cod (ICNAF Div. 5Z), 1963-1976.

Year	Total commercial catch (all countries) (metric tons)	U.S. commercial catch per day (metric tons)	U.S. adjusted catch per day (metric tons)	Standard Days Fished (unadjusted)	Standard Days Fished (adjusted)
1963	26,953	1.8	-	14,974	14,974
1964	25,165	1.0	-	25,165	25,165
1965	38,333	0.9	-	42,592	42,592
1966	52,863	1.1	-	48,057	48,057
1967	36,604	1.0	-	36,604	36,604
1968	42,757	1.4	1.2	30,541	35,631
1969	37,424	1.6	1.2	23,390	31,187
1970	25,209	2.1	1.3	12,204	19,392
1971	27,695	2.1	1.0	13,188	27,695
1972	24,630	2.6	1.0	9,473	24,630
1973	28,540	4.2	1.2	6,795	23,783
1974	26,692	3.9	1.0	6,844	26,692
1975	23,997	3.8	1.1	6,315	21,815
1976	19,442	3.9	1.2	4,985	16,202

Table 9. Atlantic cod stock size, by age (1-11 only), on Georges Bank (ICNAF Div. 5Z+SA6) (thousands of fish) derived from virtual population analysis assuming $M=0.2$ and $F=.55$ at ages 3 and older.

Year-class	YEAR																
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
1949	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1950	12	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1951	46	21	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1952	142	87	42	27	-	-	-	-	-	-	-	-	-	-	-	-	-
1953	394	258	158	97	29	-	-	-	-	-	-	-	-	-	-	-	-
1954	1,153	682	466	316	145	72	-	-	-	-	-	-	-	-	-	-	-
1955	2,551	1,611	1,062	743	411	235	143	-	-	-	-	-	-	-	-	-	-
1956	5,506	3,025	2,065	1,288	782	449	269	16	-	-	-	-	-	-	-	-	-
1957	11,871	6,889	4,304	2,859	1,709	1,109	680	94	13	-	-	-	-	-	-	-	-
1958	24,292	16,555	9,142	5,238	3,312	2,025	1,324	311	131	40	-	-	-	-	-	-	-
1959	40,434	32,852	19,506	9,369	5,209	3,294	1,920	691	272	101	30	-	-	-	-	-	-
1960	-	32,738	26,308	15,645	8,269	4,571	2,723	1,055	486	180	55	10	-	-	-	-	-
1961	-	-	26,212	21,206	14,079	7,890	4,113	1,936	917	461	198	84	19	-	-	-	-
1962	-	-	-	25,765	21,075	14,819	6,959	3,470	1,805	820	432	229	78	28	-	-	-
1963	-	-	-	-	29,518	24,207	13,036	7,150	3,214	1,695	840	498	214	95	52	-	-
1964	-	-	-	-	-	31,278	25,207	16,309	6,992	2,884	1,627	846	377	157	77	13	-
1965	-	-	-	-	-	-	34,016	27,672	17,404	6,911	3,053	1,700	619	277	147	24	5
1966	-	-	-	-	-	-	-	41,249	33,560	18,057	6,818	2,874	1,308	530	322	120	49
1967	-	-	-	-	-	-	-	-	32,646	26,586	12,920	5,573	2,003	869	429	184	78
1968	-	-	-	-	-	-	-	-	-	19,573	15,971	10,587	4,633	1,665	959	467	247
1969	-	-	-	-	-	-	-	-	-	-	19,001	15,502	9,814	3,641	1,842	1,073	452
1970	-	-	-	-	-	-	-	-	-	-	-	22,086	18,011	11,249	4,994	2,686	1,494
1971	-	-	-	-	-	-	-	-	-	-	-	-	40,828	33,335	13,495	5,364	2,058
1972	-	-	-	-	-	-	-	-	-	-	-	-	-	26,598	20,798	10,202	4,172
1973	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18,340	14,773	8,383
1974	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34,746	28,271
1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(20,000) ¹
Stock size (10 ³ fish)																	
Age 1+	86,402	94,724	89,272	82,553	84,538	89,949	90,390	99,953	97,440	77,308	60,945	59,989	77,894	78,444	61,455	69,652	65,209
Age 2+	45,968	61,986	63,060	56,788	55,020	58,641	56,374	58,704	64,794	57,735	41,944	37,903	37,066	51,846	43,115	34,906	45,209
Age 3+	21,676	29,134	36,752	35,582	33,945	34,464	31,167	31,032	31,234	31,149	25,973	22,401	19,055	18,511	22,317	20,133	16,938
Age 4+	9,805	12,579	17,246	19,937	19,866	19,645	18,131	14,723	13,830	13,092	13,053	11,814	9,241	7,262	8,822	9,931	8,555
Stock size (metric tons)																	
Age 2+	66,546	83,984	108,795	115,473	117,790	124,583	120,559	100,579	100,855	93,473	79,057	73,098	62,877	66,408	66,065	60,037	62,910
Age 3+	51,484	69,616	92,484	102,326	104,724	109,575	104,930	83,423	80,043	76,989	69,155	63,487	51,711	45,740	53,170	50,877	45,382
Age 4+	34,746	46,273	64,981	80,266	84,872	88,680	86,549	60,427	55,508	51,529	50,938	48,559	37,873	29,879	34,142	36,493	33,562

¹Estimated.

Table 10. Fishing mortality rates (F) for Atlantic cod from Georges Bank (ICNAF Div. 5Z+SA6) derived from virtual population analysis (M=0.2).

Year-class	YEAR																
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
1949	.550	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1950	.536	.550	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1951	.500	.931	.550	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1952	.292	.521	.243	.550	-	-	-	-	-	-	-	-	-	-	-	-	-
1953	.224	.292	.200	.990	.550	-	-	-	-	-	-	-	-	-	-	-	-
1954	.326	.181	.107	.577	.501	.550	-	-	-	-	-	-	-	-	-	-	-
1955	.260	.216	.157	.392	.357	.298	.550	-	-	-	-	-	-	-	-	-	-
1956	.399	.182	.272	.299	.356	.310	2.662	.550	-	-	-	-	-	-	-	-	-
1957	.344	.270	.209	.315	.233	.208	1.784	1.780	.550	-	-	-	-	-	-	-	-
1958	.183	.394	.357	.258	.292	.225	1.249	.661	1.001	.550	-	-	-	-	-	-	-
1959	.009	.321	.533	.307	.258	.340	.021	.732	.796	1.010	.550	-	-	-	-	-	-
1960	-	.019	.320	.430	.393	.310	.748	.575	.791	.996	1.514	.550	-	-	-	-	-
1961	-	-	.012	.210	.379	.451	.554	.547	.409	.645	.656	1.275	.550	-	-	-	-
1962	-	-	-	.003	.152	.556	.496	.454	.589	.441	.432	.002	.815	.550	-	-	-
1963	-	-	-	-	.002	.419	.401	.600	.439	.503	.321	.645	.615	.396	.550	-	-
1964	-	-	-	-	-	.016	.235	.647	.686	.372	.454	.609	.676	.618	1.560	.550	-
1965	-	-	-	-	-	-	.007	.264	.724	.617	.305	.811	.602	.435	1.599	1.454	.550
1966	-	-	-	-	-	-	-	.006	.420	.774	.664	.587	.703	.290	.790	.697	.550
1967	-	-	-	-	-	-	-	-	.007	.522	.641	.823	.634	.507	.648	.663	.550
1968	-	-	-	-	-	-	-	-	-	.004	.221	.628	.822	.352	.520	.435	.550
1969	-	-	-	-	-	-	-	-	-	-	.003	.257	.791	.482	.340	.664	.550
1970	-	-	-	-	-	-	-	-	-	-	-	.004	.271	.612	.420	.387	.550
1971	-	-	-	-	-	-	-	-	-	-	-	-	.004	.704	.722	.758	.550
1972	-	-	-	-	-	-	-	-	-	-	-	-	-	.046	.512	.694	.550
1973	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.016	.367	.550
1974	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.007	.100
1975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(.0186)
F ¹ 2+	.260	.324	.378	.320	.273	.435	.428	.448	.543	.606	.448	.513	.525	.647	.569	.538	.319
F ¹ 3+	.345	.320	.420	.385	.348	.447	.585	.611	.674	.678	.593	.690	.765	.544	.622	.633	.550
F ¹ 4+	.347	.241	.292	.343	.326	.364	.717	.572	.612	.546	.546	.745	.738	.440	.469	.631	.550

¹Weighted by stock size (numbers) at age.

Table 11. Percentage of fishing mortality (F) at ages 1 and 2 compared to mean F at ages 3 and older (partial recruitment).

Year	Age 1	Age 2
1960	2.6	53.0
1961	5.8	97.9
1962	2.9	76.2
1963	0.8	54.5
1964	0.6	43.7
1965	3.6	93.7
1966	1.2	40.2
1967	1.0	43.2
1968	1.0	62.3
1969	0.6	77.0
1970	0.5	37.3
1971	0.6	37.2
1972	0.5	35.4
1973	2.9	129.4
1974	2.6	82.3
1975	1.1	58.0
1976	3.4	32.7

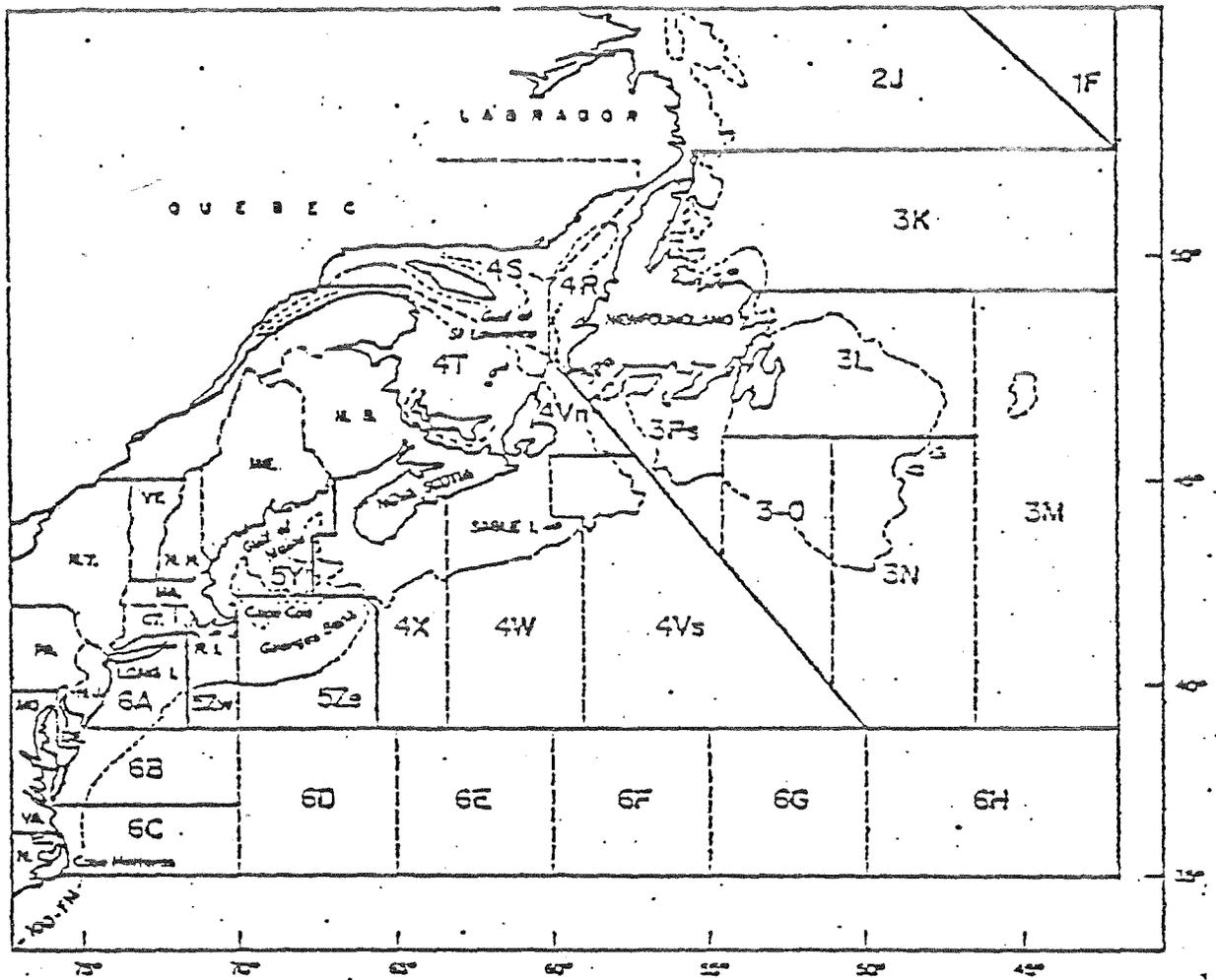


Figure 1. Northwest Atlantic from North Carolina to Labrador showing ICNAF SA 3-6.

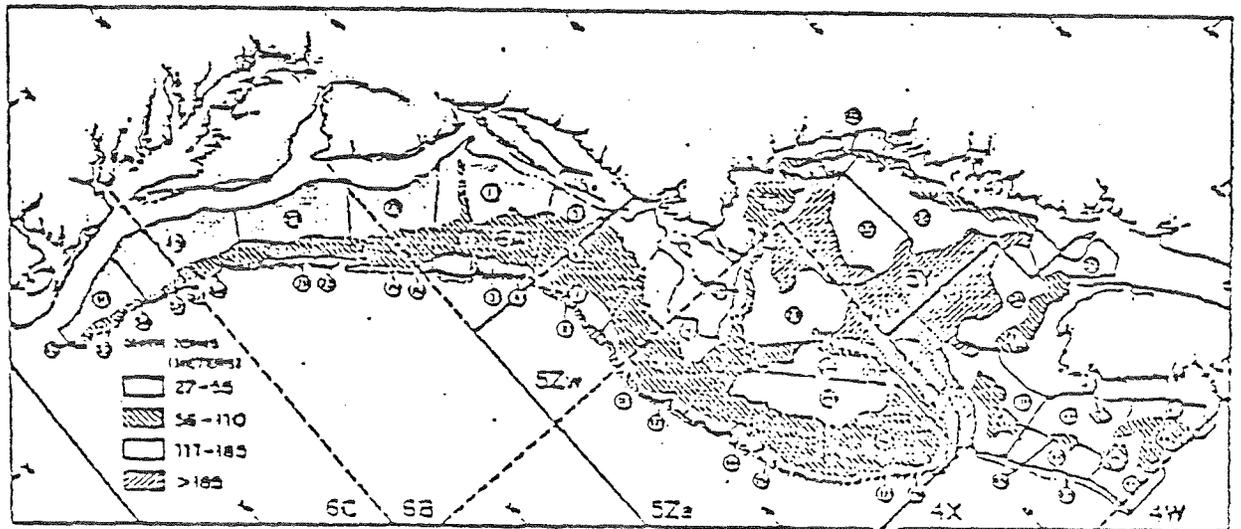


Figure 2. Northwest Atlantic off the USA coast showing bottom trawl survey sampling strata and ICNAF SA 5-6.

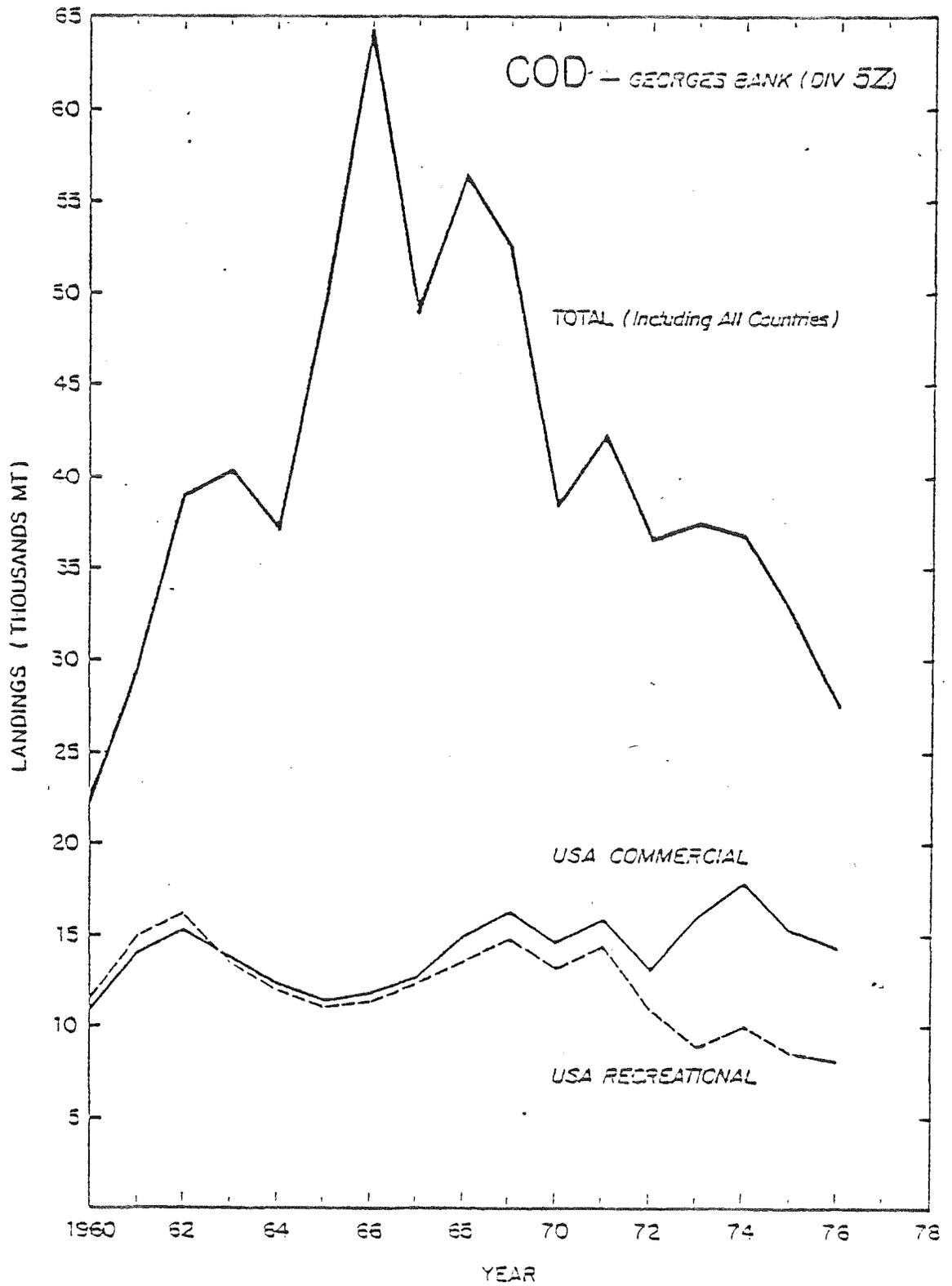


Figure 3. Cod landings from Georges Bank (ICNAF Div. 5Z) during 1960-1976.

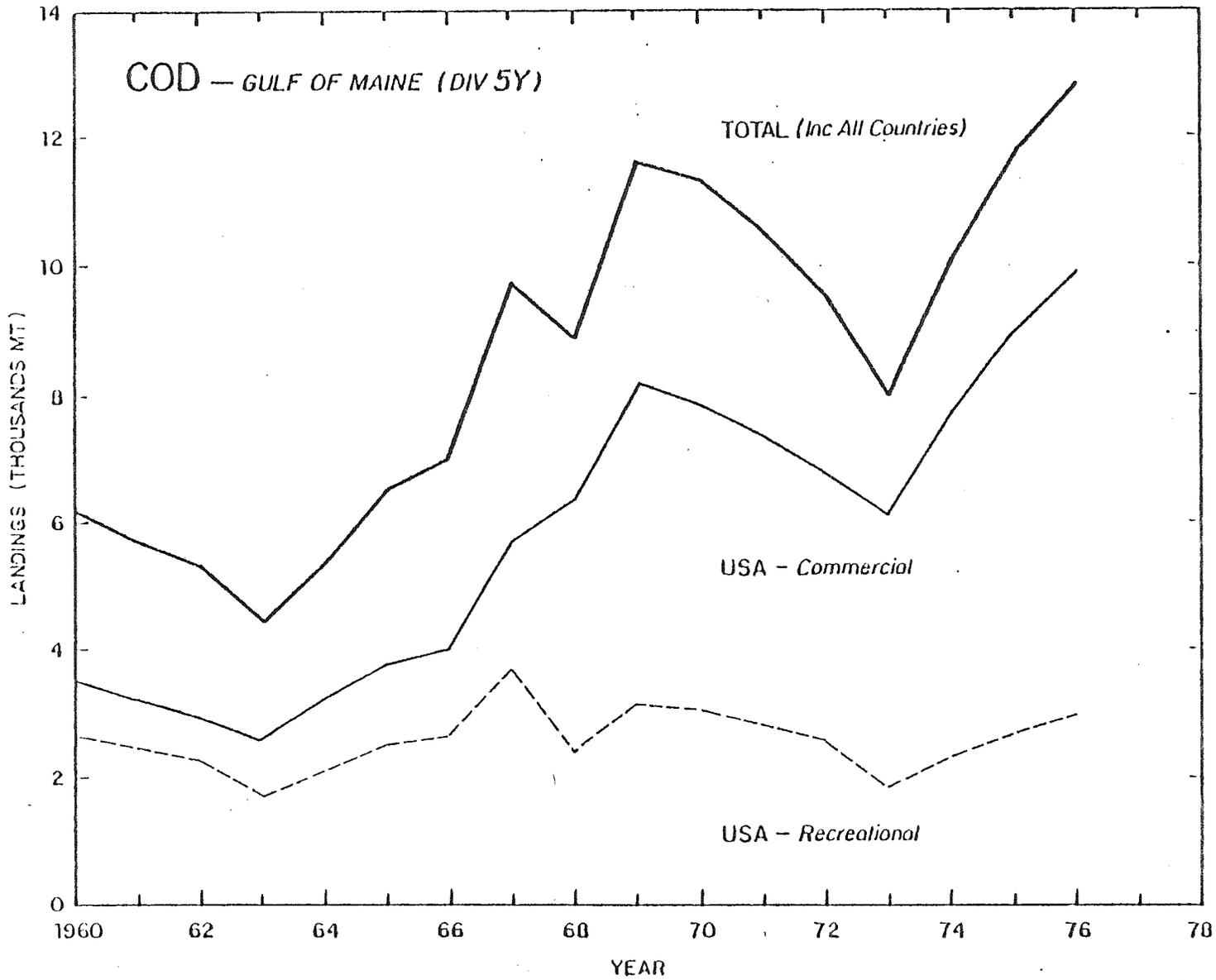


Figure 4. Cod landings from the Gulf of Maine (ICNAF Div. 5Y) 1960-1976.

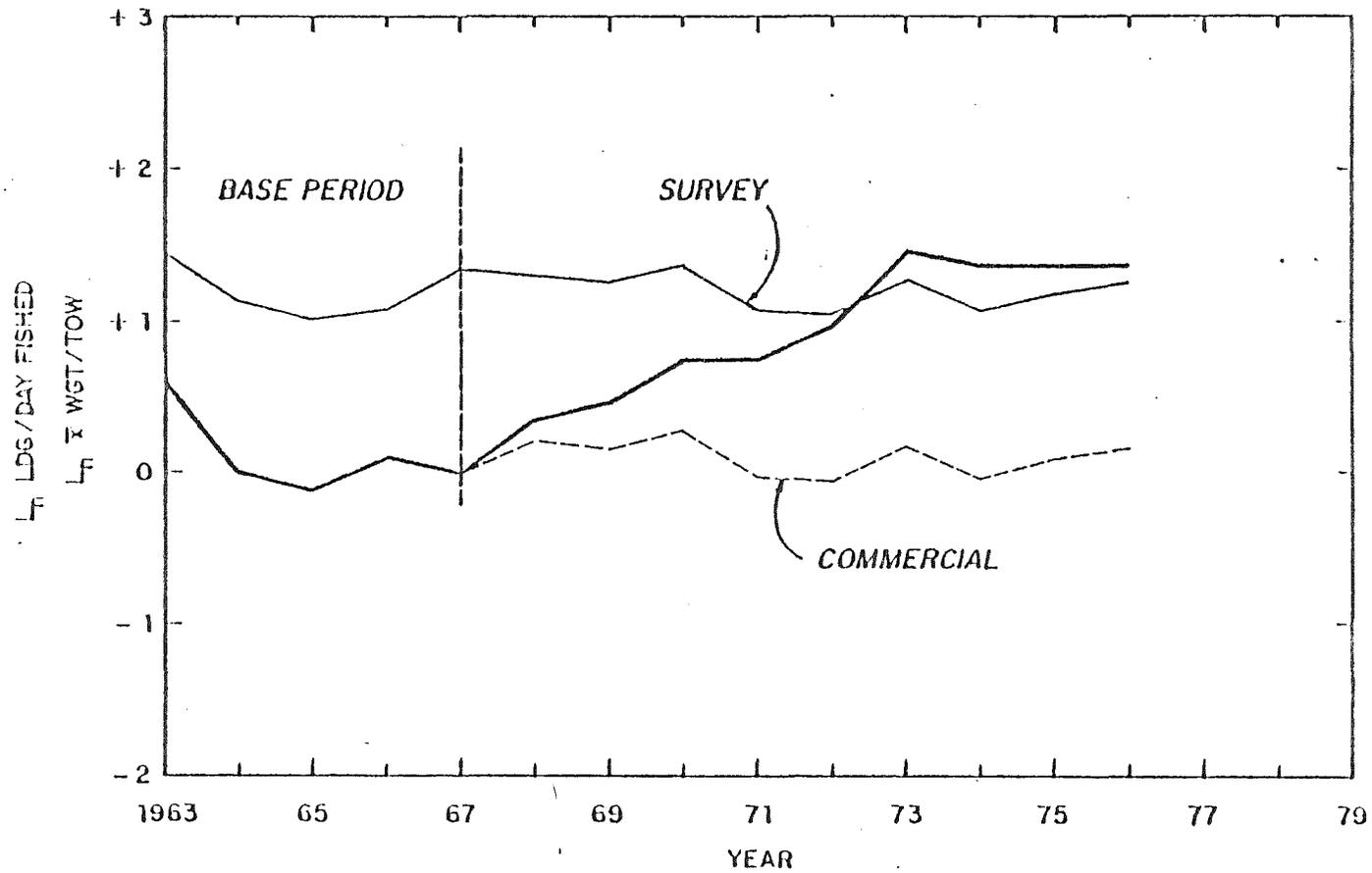


Figure 5. USA commercial landings-per-day (\log_e)(MT $\times 10^{-3}$) of cod from Georges Bank, and USA autumn bottom trawl survey catch-per-tow (\log_e)(pounds) indices, 1963-76.

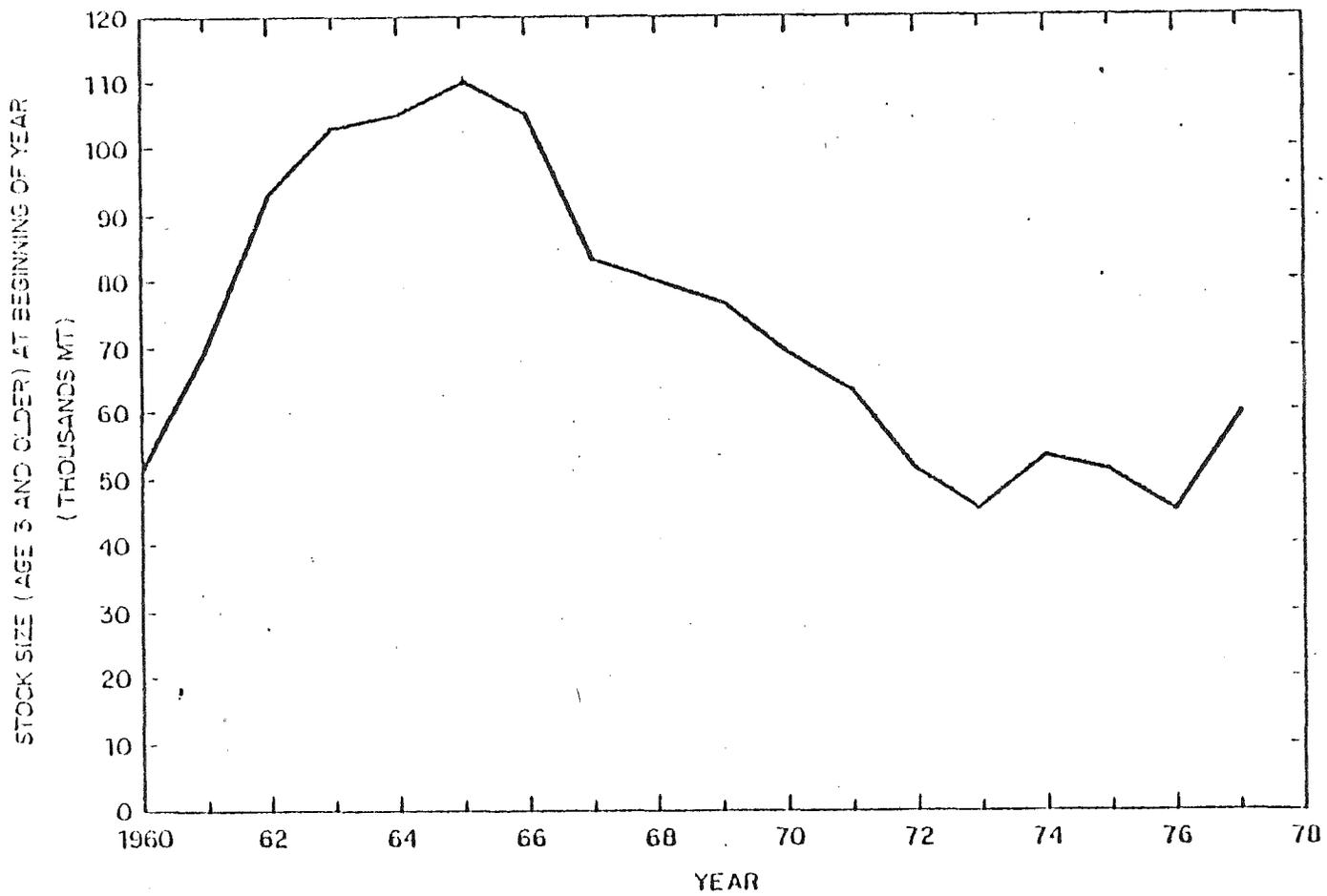


Figure 6. Georges Bank cod spawning stock biomass, 1960-77, derived from virtual population analysis.